IMPLEMENTING 4-DIMENSIONAL FORCE PROTECTION MEASURES AT FORWARD OPERATING BASES

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ABSTRACT

Identifying and bridging the technology gap to provide spherical (above and below ground) force protection measures that detect and monitor covert operations targeting secure facilities is of particular importance given recent successful breaches via subsurface tunnels. Seismic and acoustic technologies have identified the signatures of typical digging activity and other associated subsurface activity at depths up to seven meters. By deploying an array of these sensors around a secure facility it is possible to monitor clandestine tunneling activity in real-time with high confidence and only minimal impact to ongoing base camp operations.

INTRODUCTION

The protection of secure facilities, such as Forward Operating Bases (FOB) and detainee facilities is an emerging issue in light of unsuccessful and successful undetected egress/ingress tunnels at overseas bases, borders, and other locations where terrorists are held. The Armed Forces are investigating sensor modalities to protect secure facilities because covert tunnels can conceal and protect terrorist activities, weapons of mass destruction, command and control facilities, and other functions. In general, because these structures are situated in widely varying geo-environments and possess varying degrees of internal infrastructure (power conduits, HVAC, re-enforced concrete, other metallic objects) no one specific technology can support all potential detection requirements. Currently available seismic and acoustic technology can be used to span the underground protection gap within our Force Protection strategy. The same methodology can also successfully protect secure facilities along our borders.

Initial studies were conducted at a base camp in Iraq in July-November of 2005. In addition to the authors, a team of researchers led by Dr. Michael Mattice (US Army Rapid Engineering Force) and including Mr. Michael Bishop, Ms. Alana Lester, Mr. Jose Llopis, and Dr. Janet Simms (U.S. Army Engineer Research and Development Center), in addition to other personnel from governmental intelligence agencies tested several geophysical systems. However, the most promising technology used an array of acoustic and seismic sensors placed at various depths to characterize various signatures produced by subsurface tunneling and other common equipment associated with base camp operations (including vehicle motion). Subsequent analysis determined that local geologic characteristics were of primary importance in governing both surface and subsurface signals of interest.

SITE GEOLOGY

The general geologic setting of the camp consists of various layers of fine grained sediments from surficial wind blown silts and sands to compacted silt and clay bearing layers with varying amounts of gypsum and unconsolidated course to fine sands at the 7 m depth. All sediments are damp below about 1 m.

The wind blown material is typically very fine and well rounded. This mixture of quartz and probably feldspars and minor other mineral grains becomes extremely hard and essentially cemented at about 30 cm apparently due to precipitating gypsum minerals. This layer gives way to between three or four distinct layers of buff or tan layers intermixed with gray green layers of compacted silts with varying amounts of clay sized particles and a fair amount of clay minerals as well. These layers vary in depth and vertical extent depending on the location within the camp. In the upper layer the gypsum forms veinlets some 5 mm in diameter and spaced quite closely throughout the layer. Some crystals of gypsum up to 3 cm in length have been noted. The lowest levels of sediments typically do not contain distinct gypsum veins or crystals.

At some locations there is are large areas of a white, very course and loosely aggregated mineral that is locally called “getch” (see Figure 1). This material is suspected to be calcium sulfate without the waters of hydration. When water is mixed with a 50/50 mixture of this fine grained mineral and other surficial material an extremely hard block is formed. This material is used to

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **01 NOV 2006**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Implementing 4-Dimensional Force Protection Measures At Forward Operating Bases**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **MANSCEN Futures Center, Fort Leonard Wood, MO 65473**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002075., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

make roads and hardened areas for construction in the local community.

Figure 1. A layer of "Getch" found about 20 cm below the surface. This layer was about 10 cm thick.

Figure 2. Top layer of unconsolidated soil; below is silt/clay with white mineral ($CaSO_4$).

The different layers of silt vary in thickness and color on both the horizontal and vertical axis. At about 6.5 to 7 meters, a thick sequence of unconsolidated sand is encountered. The vertical extent of the lowest course to fine to medium grained sand layer is not known but it does extend at least 1 meter below the tunnel floor. The sand layer has visibly distinct bedding planes slanting at all angles.

Within this sand layer are hard dark mineral clots found as radiating spheres extending 1 to 3 cm in diameter. There are also up to 1 cm wide veinlets that normally extend less than 5 cm in length. These features are abundant in the upper part of the unconsolidated sand layer and are found in the reddish silt layer near the contact (which in some cases is more gradational than knife edge. The overlying silt slumps into the sand layer at many locations. These hard mineral occurrences are generally found within 30 cm of the contact and are sufficiently hardened that distinct impact sounds are generated when struck with an entrenching tool or chisel.

Figure 3. Typical strata sequence in the study area. Note the subtle lateral color changes and weathering profile differences.

To validate sensor performance, we designed and constructed a 24 ft vertical shaft with an interior side dimension of 4 ft. Camp personnel excavated a pit with a vertical wall facing east (Figure 4). The vertical shaft was lowered into the hole so that the tunnel would be right at the silt-sand contact, which was at 7 meters in this particular location. This allowed about 1 meter of the shaft to stick up above ground. A head frame was attached to the shaft and a pulley system attached in order to lift the spoils from the tunnel construction. About 0.25 cubic feet of spoil were removed at a time (about 1/3 of a five gallon bucket).

The tunnel leaving the shaft was about a meter in diameter, supported by a series of vertical posts with 2 x 6 lumber on the top and sides as the shoring. The tunnel was dug into the sand layer and almost immediately, the slit layer slumped into the course of the tunnel from the right, leaving slightly less than half of the working face as unconsolidated sand. Thus, the back and right side of the tunnel was constructed in hard silt. It took about 3 days to dig the tunnel to the desired length (6m) meters before testing was initiated. The data collection was initiated at this length in an attempt to minimize any back scatter problems from the digging operations and unwanted clutter noise coming down the shaft and into the tunnel. Our analysis of the data could not detect any such spurious acoustic or seismic contamination.

Figure 4. Shaft in place. Note the various layers.

Figure 5. At the bottom of the shaft as the tunnel or adit is going into the unconsolidated – silt interface. Note the bedding plans outlined by stained grains in the unconsolidated sand layer.

Figure 6. A look down the adit to the working face.

Figure 7. Surface layout of the data collection array. Tunnel direction is in direction of tunnel

The data collection sensors were placed normal to the direction of the tunnel and perpendicular to the tunnel (see Figure 8). The sensors were also placed at varying depths to determine the attenuation capabilities of the layers for sounds generated at the surface and in the tunnel (e.g., trucks, generators, walking, digging). A variety of data was collected during actual underground digging operations. The digging was completed with tools similar to those used by detainees to construct their own tunnels.

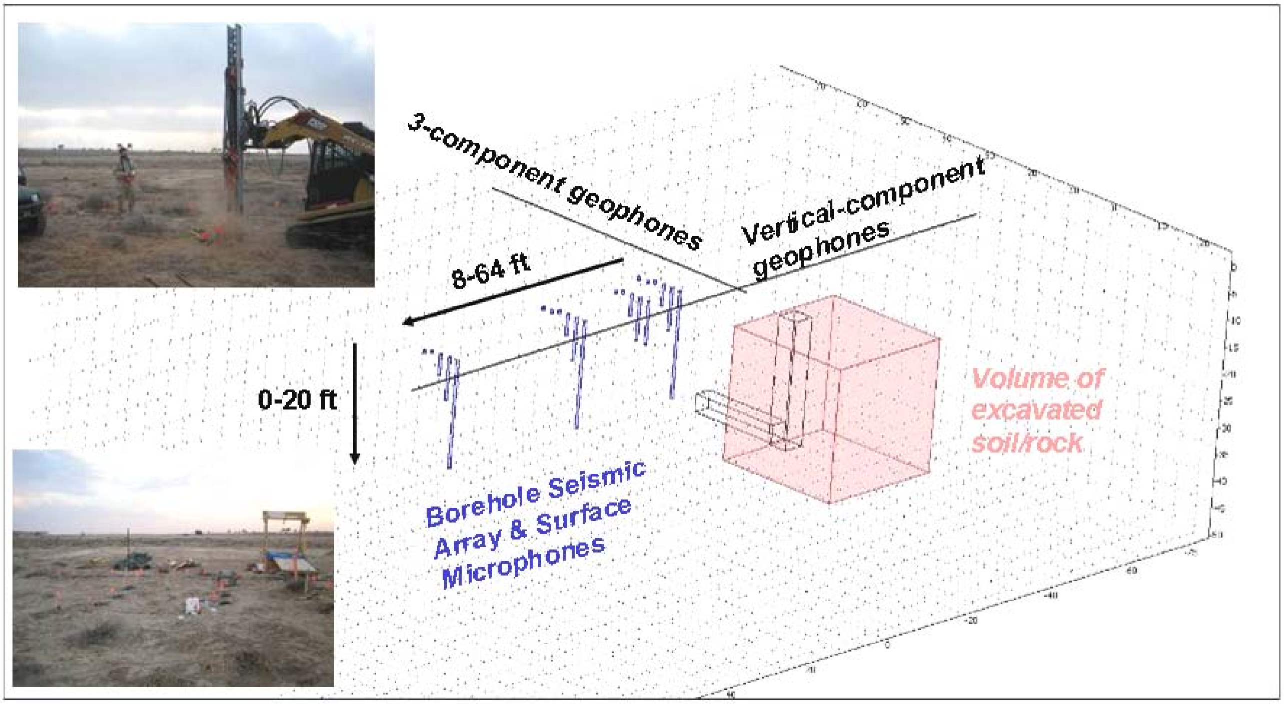

Figure 8. Seismic-acoustic sensor lay-down showing an array of vertical geophones installed to determine the Attenuation of sounds generated at the surface and in the tunnel.

FORCE PROTECTION MODELS

CONUS analysis of the test data with BBN Technologies indicate that passive seismic and acoustic collection arrays will detect and classify active digging operations near a protected facility after advanced signal processing is performed (see Figures 9-10). Such a system can be emplaced with a minimal surface footprint and impact of facility operations. There are five concerns that need to be addressed to take full advantage of this technology: first, designing and integrating the seismic-acoustic array into the over all security plans of the facility; second, constructing the array in conjunction with the facility to minimize costs and maximize effectiveness; third, collecting enough data to categorize the cultural signatures within and near the facility in order to integrate these signatures into the detection algorithm; fourth, training the facility managers on the system and how to recognize anomalies (i.e., if actual tunneling occurs); and fifth, maintaining reach-back to the system administrator to provide expert interpretation, trouble shooting advice, and additional upgrades as situations change.

All of these services are to ensure the false positive rate is kept to a negligible rate. One solution is to provide the facility with its own tunnel, where periodic testing of the sensor array would originate. This negative Z detection capability provides commanders confidence in their force protection technologies.

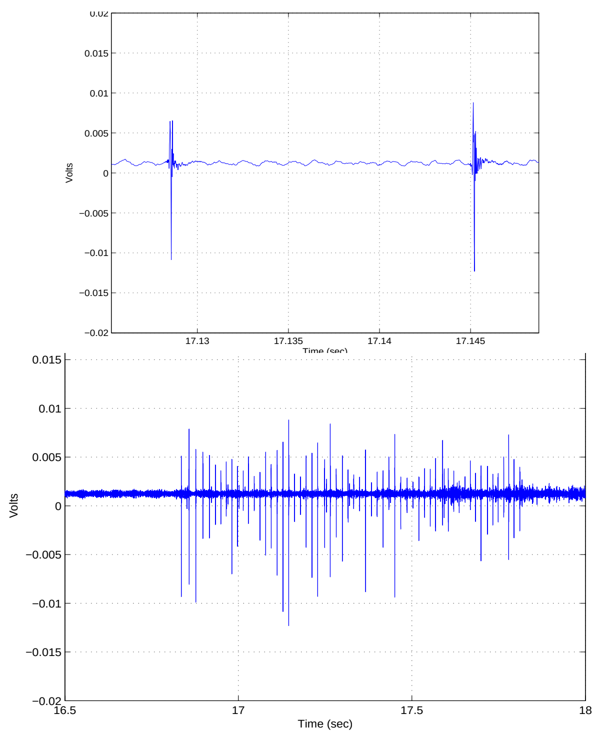

Figure 9. Time series of digging signals performed with a small section of rebar.

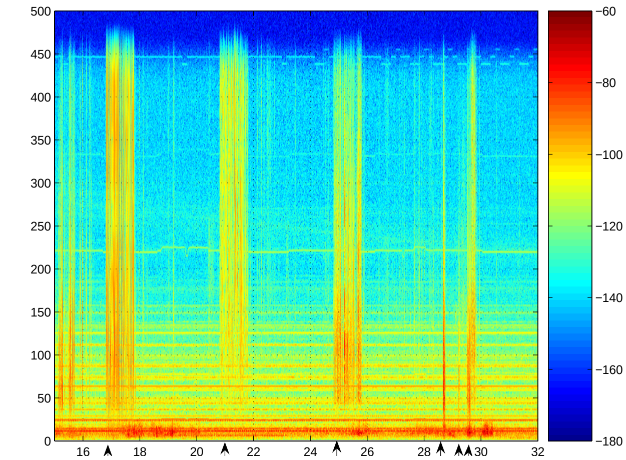

Figure 10. Spectrogram of digging signals from vertical geophone at depth.

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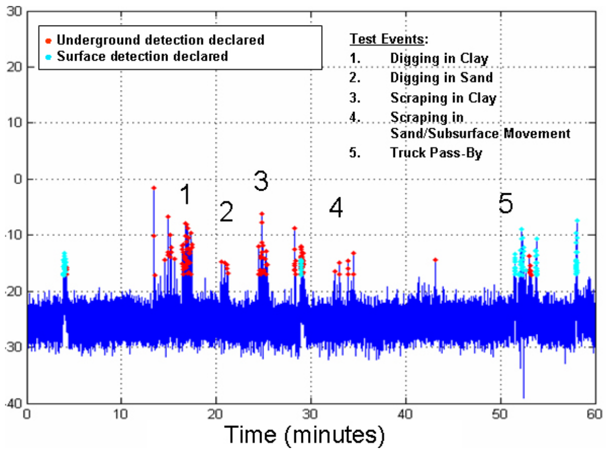

Figure 10. Results of signal processing to automatically differentiate and classify signals originating from the surface and underground.

To illustrate the utility of such a force protection model globally, consider the Otay Mesa tunnel discovered on 26 January 2006. The tunnel, one of four located within a two-week period between Tijuana and San Diego, is the longest and most sophisticated tunnel ever found under the US southern border.

The tunnel is approximately 2,400 ft long (731 m) and began in a warehouse near the Tijuana Airport. It follows a northeasterly route to a warehouse located on American soil in Otay Mesa, California. The entrance on the US side was built through a tile floor concealed in an office of the warehouse. This tunnel is about 1000 ft longer than the previously discovered 1993 tunnel.

Soil sampled in the current tunnel was very moist, sandy and contained large (at least 4 cm) clasts of volcanic tuff. Layers of clay were interbedded with the sandy material and white concretions were visible throughout. Figure 11 is a view of the Otay Mesa formation.

In this area, the geology is very similar to that encountered overseas.

Figure 11. Otay Mesa formation. Note the similar geology to that overseas.

Seismic-acoustic signals from digging appear very similar. Here however, ambient noise is much more intense. Despite the presence of numerous trucks idling near sensors, the signals of interest are clearly visible.

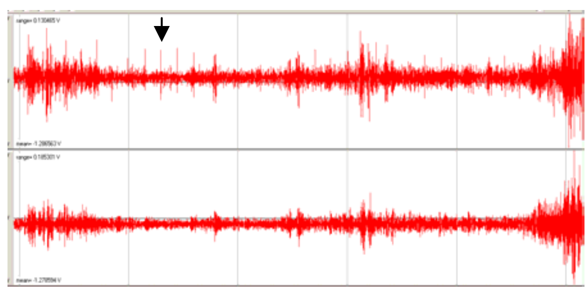

Figure 12a. Digging activity along US southwestern border. Arrow points to signals of interest.

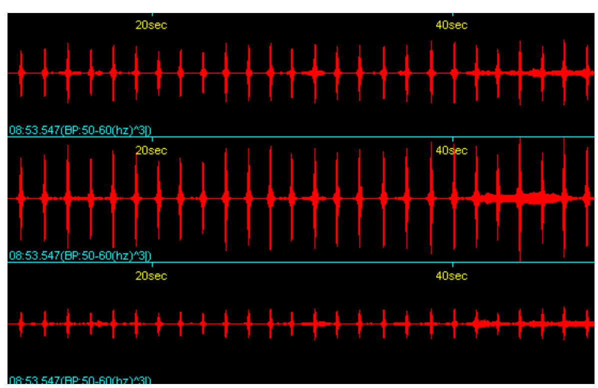

Figure 12c. Filtered closeup of digging activity along US southwestern border

CONCLUSIONS

Protecting the negative Z component is the next capability gap to be bridged in the Force Protection arena. The potential subsurface penetration of secure facilities represents a significant gap in our current Force Protection models and capabilities. Force Protection of secure facilities requires a system that can monitor or detect any attempts at subsurface penetration, must use current technologies for immediate operational employment and upgrades, considered during the earliest planning phase of facility construction and integrated into the construction scheme, and be easily monitored by personnel at the site with constant technical reach back ability. The use of seismic and acoustic sensors provides the facility commander with an excellent passive data collection capability that our experiments showed can readily distinguish tunneling activities from the flood of surface originating anthropomorphic sounds encountered on a base.

The system is designed for on-site monitoring. With modest training, testing in a live tunnel and real time reach back quality control, the rate of false positives could be substantially low. All these capabilities can give the commander confidence in his force protection capabilities.

ACKNOWLEDGMENTS

The authors wish to thank the 43rd MP BN Iraq, for supporting the deployment. Additionally we wish to thank BBN Technologies for helping support OCONUS field collection and analysis, and Support of this effort was provided by the US Army Rapid Equipping Force to ERDC-GSL. Director, Geotechnical and Structures Laboratory, U.S. Army Engineer Research & Development Center, granted permission to publish.